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THEORY OF THE VISCOSITY OF HELIUM II:
PART 2. CALCULATION OF THE COEFFICIENT OF VISCOSITY

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[A Digest]

The coefficient of viscosity of ordinary fluids decreases with temperature; thus, if eta η represents this coefficient of viscosity, then its derivative with respect to temperature T, namely $d\eta/dT$, is negative. It is found that $d\eta/dT$ for helium II is negative everywhere except for a small region near the lambda point. Therefore, the temperature variation of helium II's coefficient of viscosity cannot follow the law asserted by L. Tisza (see Phys Rev, 72, 839, 1947), namely $\eta \approx T^{\frac{1}{2}}$ or the earlier equally erroneous relation $\eta \approx T^5$.

Quantitatively, $\eta(T)$ has been determined for the intervals $T < 0.8°K$ and $T > 1°K$ after lengthly theoretical considerations:

$$\eta = 7.8 \cdot 10^{-5} (T^{\frac{1}{2}} \exp - \Delta/kT + 4.8 \cdot 10^{-6} T^5)^{-1} \qquad T < 0.8°K$$

$$\eta = 1 + (8.7 \cdot 10^{-4}) T^{-\frac{1}{2}} \exp \Delta/kT \qquad T > 1°K$$

in units of 10^{-5} poise.

Thus helium II's coefficient of viscosity follows the law T^{-5} for $T < 0.7°K$ and the law $T^{-\frac{1}{2}} \exp \Delta/kT$ for $T > 1.0°K$; and the above complicated law governs the intermediate area between 0.7° and 1.0°K (η at $T \approx 0.9°K$ is found by extrapolation).

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Actually, the above-mentioned coefficient of viscosity is the total viscosity; that is, it is the sum of the so-called roton viscosity and phonon viscosity. Thus, theory shows that η_r (roton viscosity) is independent of temperature and equals $1 \cdot 10^{-5}$ poise. It is η_ϕ(phonon viscosity) that varies with T.

The kinetic equations for roton and phonon viscosity were solved by use of the effective differential cross sections of scattering of the elementary excitations, phonons and rotons, which were obtained in Part I of this work. Simplifying assumptions were made in order to effect a solution. Thus, the distribution function n for rotons (or phonons) was assumed to be close to its equilibrium function n_0; the sought-for stationary solution permitted the elimination of partial derivatives with respect to time t; also, the collision angles were assumed to be small; etc.

Of course, the analysis was carried out separately for the two temperature intervals $T < 0.8°K$ and $T > 1.0°K$ because of the different sets of simplifying assumptions required as to the magnitude of the colliding and rebounding momenta p, p_1, p', p_1' in comparison with the momentum of kT/c.

Theoretical results were in good agreement with the experimental data of E. Andronikashvili (ZhETF, Vol 18, p 429, 1948).

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